Energy, Mines and Resources Canada | Energie, Mines et Ressources Canada

CANMET

Canada Centre for Mineral and Energy Technology | Centre canadien de la technologie des minéraux et de l'énergie

THE COMBUSTION OF HAT CREEK COALY WASTE IN AN ATMOSPHERIC FLUIDIZED BED COMBUSTOR

E.J. Anthony, D.L. Desai and F.D. Friedrich

January 1983

This document is an unpublished internal report prepared primarily for discussion and internal publishing purposes. It may subsequently be published as a final report, but the opinion of the Canada Centre for Mineral and Energy Technology (CANMET)

Ce document est un rapport interne préparé principalement pour discussion et publication internes. Il peut subséquemment être publié comme rapport final, mais l'opinion du Centre canadien de la technologie des minéraux et de l'énergie (CANMET)

15pp

ENERGY RESEARCH PROGRAM
ENERGY RESEARCH LABORATORIES
ERP/ERL 82-54(TR)

MICROMEDIA
JUL 29 1983

THE COMBUSTION OF HAT CREEK COALY WASTE IN AN ATMOSPHERIC FLUDIZED BED COMBUSTOR

by

E.J. Anthony*, D.L. Desai** and F.D. Friedrich*

ABSTRACT

Hat Creek coaly waste, containing 44% ash and 17% moisture, was burnt in an atmoshperic fluidized-bed combustor at combustion efficiencies over 97%. Efficiencies up to 99% were achieved when feeding the coaly waste in-bed rather than overbed.

The ash from the coaly waste, which produced a "B" type powder according to Geldart's classification, allowed the bed to operate in the bubbling and slugging regimes over fluidizing velocities ranging from 1 to 2.5 m/s.

By optimizing carbon burn-out with bed temperatures and coal feed arrangement, a high proportion of the alumina in the clay was removed in an acid recoverable form.

---

* Research Scientist, Energy Research Laboratories, CANMET.

** Research Engineer, Energy Research Laboratories, CANMET.

INTRODUCTION

The Combustion and Carbonization Research Laboratory (CCRL) conducted a series of fluidized-bed combustions trials on coaly waste from the sub-bituminous Hat Creek coal deposit in central British Columbia. This waste, which was high in alumina and low in sulphur, had a calorific value of 8.7 MJ/kg at 17% moisture.

The combustion trials were designed to maximize carbon burn-out, without transforming the clayey ash components into crystalline forms of alumina; the non-crystalline bed ash was subsequently used as a feedstock for research on an acid-exhaustable alumina recovery process (1, 2, 3).

This report describes the research facility and procedures used and gives an evaluation of the experimental combustion data.

The objectives of the project were:

RESEARCH OBJECTIVES

1. To determine the bed conditions necessary to achieve high combustion efficiencies (> 98%) of the high ash coaly waste, and
2. To produce residual bed ashes, suitable for acid extractions of alumina, with known temperature histories.

PILOT-SCALE FLUIDIZED-BED FACILITY

The pilot-scale facility, illustrated in Figures 1, 2 and 3, has been described in detail elsewhere (4). It consisted of a 0.24 m ID x 1.2 m high combustor, a 0.6 ID x 1.8 m high freeboard sections with a conical bottom, and a multicyclone dust collector to collect coarse fly ash. The coal feed rate, which could be injected either in or over the bed, was controlled by a variable-speed, plate feeder.

Instrumentation on the facility measured bed pressure and temperature at four levels in the combustor; temperatures at two levels in the freeboard; flue gas analysis; cyclones ash; fly ash loading beyond the cyclone; bed overflow ash; and combustible in each ash fraction.

EXPERIMENTAL PROCEDURE

The original bed material was obtained by ashing coaly waste in a muffle oven at 700°C or less. The bed material was heated to about 500°C by a submerged propane burner. Coaly waste was then injected into the combustor via either an in-bed or an overbed feeder and bed temperatures were controlled by the coal feed rate and the excess combustion air level.

Bed heights were controlled by intermittent ash removal through a discharge pipe in the centre of the distributor plate.

The coaly waste, the analysis of which are given in Table 1, was burned in a series of 22 combustion tests. Control parameters for the tests are summarized below:

Bed height - initial	300 mm
- maximum	610 mm
Bed temperature	700° to 1100°C in 50°C steps
Superficial velocities	1.0 to 2.5 m/s
Coal feed rates	14 - 41 kg/h
Excess combustion air	30 - 170%
Test duration	1.5 to 8.0 h

EXPERIMENTAL RESULTS

Of the 22 tests, 8 employed an in-bed feed whereas the remainder employed an overbed feed. The data for the bed operating conditions, Table 2, the theoretical and measured flue gas compositions, Table 3, and the ultimate analysis of the coaly waste given in Table 1, were used to obtain statistical correlations of precision between the input values and the output results. Using the "t-test" and the Mann-Whitney "U" statistic, it was found that the CO_2 measurements were satisfactory, but that the O_2 measurements were consistently about 25% too low; subsequently, the oxygen analyzer was found to yield low O_2 values.

COMBUSTION EFFICIENCY

The average combustible in ash from various parts of the system and the corresponding combustion efficiencies for selected tests, Table 4, varied

from 1 to 3.3% of the fuel carbon input indicating that the coaly waste was highly reactive. Typically, the combustible in the bed ash and the cyclone ash was 0.1% and 2-3% respectively. As expected, the combustible in ash from the in-bed feed tests was lower than the over-bed feed tests because of the longer residence times available for carbon burn-out when fuel is injected into the burning bed.

ASH BALANCE

The mass of ash recovered from various parts of the system varied from 81% to 154% of the input ash as determined from the ultimate analysis. A statistical analysis of the weight of ash generated from 19 of the 22 tests indicated that the difference between the theoretical and measured weights of ash for each test was due to random rather than systematic errors. It was established that these random errors were due to problems associated with obtaining an accurate measurement of ash at the beginning and end of each test. As mentioned previously, a bed level of 300 mm was used as the starting and final reference for determining the amount of ash generated.

Ash elutriation was in all tests, higher for overbed than for in-bed feeding. The mean values of elutriated ash for the tests with overbed feeding was 50% compared to 36% with in-bed feeding.

FLUIDIZATION CHARACTERISTICS

Table 5 gives the sieve analysis of the bed material for bed tempratures of 800° and 900°C. The mean particle sizes of the two samples which were 0.61 and 0.84 mm respectively, these results are typical of the variation in size calculated from the formula:

where,

$dp = (\Sigma\, x_i/dp_i)^{-1}$,

dp = the mean particle size,

x_i = mass fraction trapped between sieve sizes, i and i + 1,

dp_i = average of sieves sizes, i and i + 1).

These figures defined a bed material that can be classified as a group B material at ambient conditions with air as the fluidizing medium (5, 6).

The calculated minimum fluidized velocity varied between 0.5 to 0.9 m/s using the correlation presented by Kunii and Levenspiel (7). This implied that for all of the in-bed and eight of the 14 overbed feed tests, the fluid bed operated in a slugging regime; in the remainder of the tests a bubbling regime probably prevailed.

CONCLUSION

Hat Creek coaly waste was burnt in a pilot-scale atmospheric fludized bed combustor without ash recylce, with combustion efficiencies over 98%.

Ash elutriation from the bed increased from 36% to 50% of the input ash when overbed rather than the normal in-bed feed system was used.

The bed material generated during combustion was classified as a group B powder for fluidization purposes and was subsequently found to be an excellent feedstock for an acid extraction, alumina recovery process.

REFERENCES

1. Hamer, C.A. "Alumina from fludized bed combustion of Hat Creek, B.C., coaly wastes"; Part 1: Acid Extraction MRP/MSL 79-21(IR); Feb. 1979. Part 2: Alumina Recovery and Purification by an HCL Process MRP/MSL 79-144(IR); Oct. 1979. Part 3: Alumina Recovery and Purification by an HCL - Caustic Process MRP/MSL 80-152(IR); Nov. 1980.

2. Hamer, C.A. "Acid extraction of alumina from Canadian non bauxite source at CANMET"; CANMET Report 81-2E; Feb. 1981.

3. Hamer, C.A. "Recovery of alumina from coal rejects"; coal: Phoenix of the '80s - Proceedings 64th CIC Coal Symposium - A.M. Al Taweel, editor, C.S. Ch. E.; Ottawa (1982).

4. Anthony, E.J., Desai, D.L. and Friedrich, F.D. "The design and operation of the Mark I atmospheric fludized bed combustor at the Canadian Combustion Research Laboratory"; to be published.

5. Geldart, D. "The effect of particle size and size distribution on the behaviour of gas fluidized beds"; Powder Technology 6, 201-215; 1972.

6. Geldart, D. "Types of gas fluidization"; Powder Technology 7, 285-292; 1973.

7. Kunii, D. and Levenspiel, O. "Fluidization Engineering"; published Robert E. Krieger (1977).

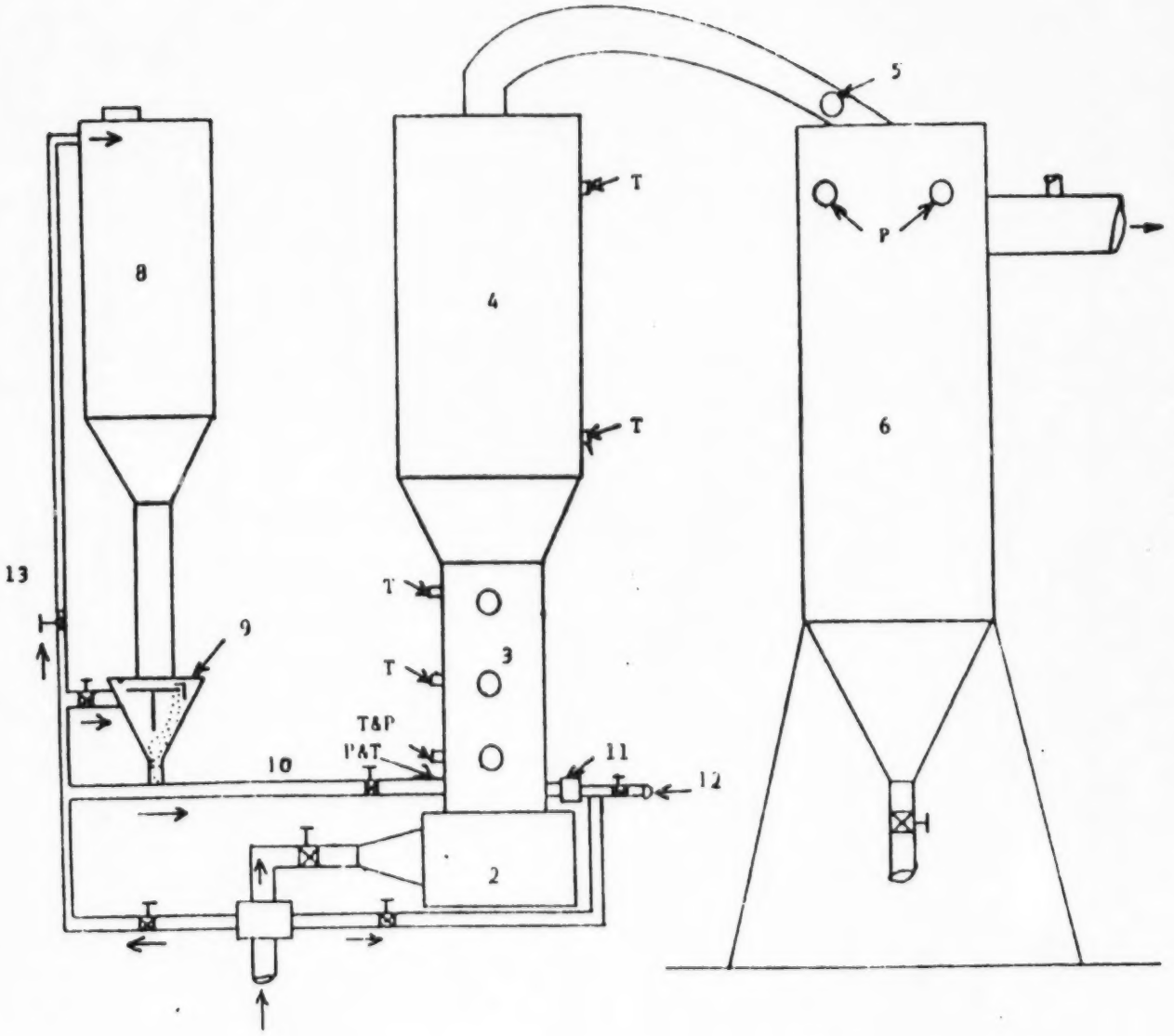
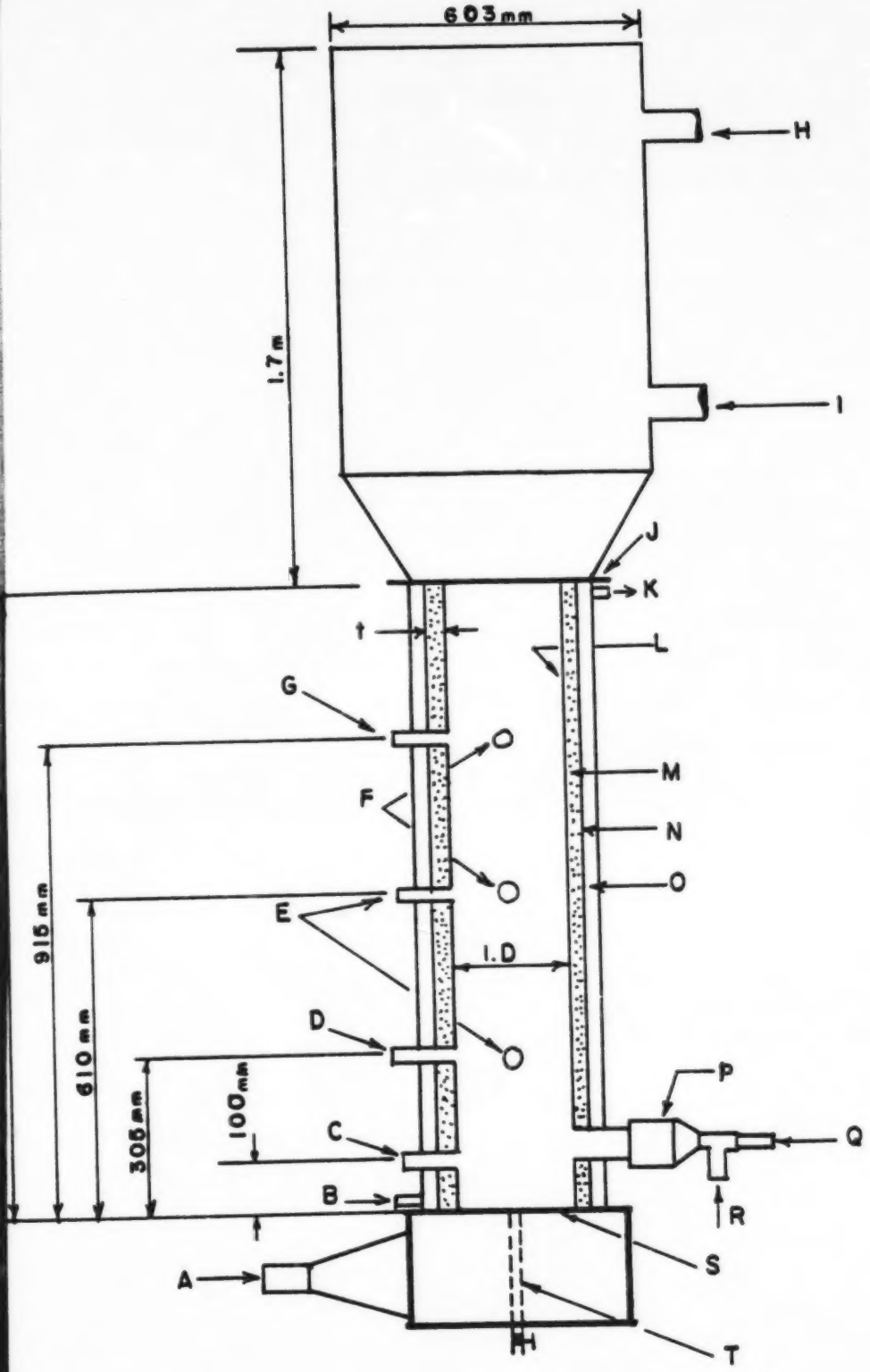


Fig. 1 Schematic of the fluid combustor and ancillary equippment



A- combustion air
B-water in
C-feed, thermocouple and pressure tapping
D-pressure tapping
E-thermocouples
F-viewing ports
G,H,I-thermocouples
J-circular flange
K-water out
L-Inconel combustor line.
M-castable refractory insulation
N-stainless steel water jacket liner
O-water jacket
P-propane air light up burner
Q-propane
R-air
S-air distributor plate
T-pipe to remove bed material

Furnace ID=241 mm
Refractory thickness(t) =22mm

Fig.2 SCHEMATIC OF COMBUSTOR AND FREEBOARD

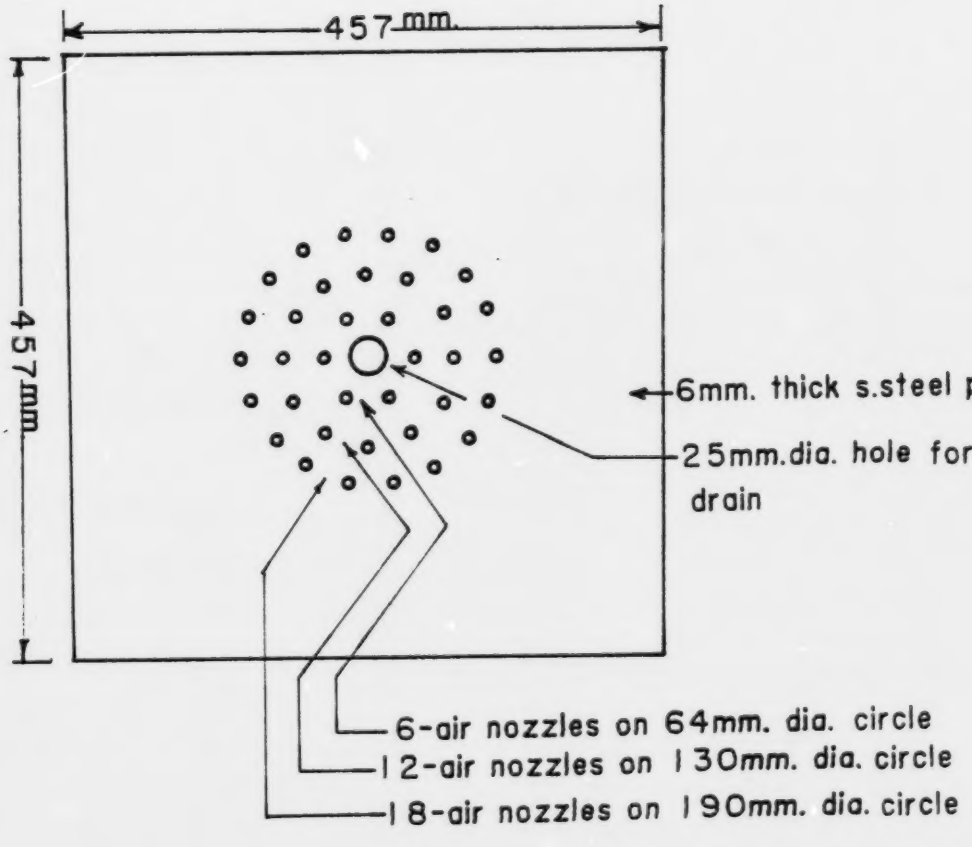


Fig.3 SCHEMATIC OF AIR DISTRIBUTOR PLATE

Table 1 - Analysis of Hat Creek coaly waste

Proximate Analysis (wt%)		
	Air dried	dried
Mositure	17.0	0.0
Ash	44.0	53.0
Volatile matter	22.0	26.5
Fixed carbon	17.0	20.5

Ultimate Analysis (wt%)		
	Air dried	dried
Carbon	25.5	30.8
Hydrogen	0.4	0.5
Sulphur	0.5	0.6
Nitrogen	0.9	1.1
Ash	44.0	53.0
Oxygen (by difference)	11.7	14.1
Moisture	17.0	0.0

Table 2 - Bed operating conditions

Test No.	Mode of fuel feed	Total fuel burnt (kg)	Duration (h)	Average feed rate (kg/h)	Volumetric air flow at 15°C (m^3/h)	Bed temp. °C	Fluidizing velocity m/s	Heat input MJ/m^2h
1	Inbed	80.5	4.9	20.0	107.9	769	2.4	3.808
2	"	52.5	3.5	14.1	86.1	770	1.9	2.685
3	"	56.0	3.0	18.2	81.0	796	1.8	3.465
4	"	23.5	1.6	17.0	75.0	829	1.7	3.237
5	"	101.5	6.2	16.2	61.2	874	1.5	3.084
6	"	41.5	3.5	18.5	62.6	926	1.6	3.522
7	"	91.5	5.9	16.2	52.4	967	1.4	3.084
8	"	72.0	4.1	20.8	67.7	962	1.8	3.960
9	Overbed	132.0	6.0	21.5	91.3	711	1.4	4.094
10	"	32.0	2.1	16.0	71.5	709	1.0	3.047
11	"	100.0	5.1	19.6	78.4	711	1.1	3.732
12	"	86.5	4.6	16.8	69.7	751	1.0	3.206
13	"	77.5	3.4	18.1	66.3	798	1.0	3.452
14	"	76.5	3.2	24.0	67.7	845	1.0	4.570
15	"	94.5	2.6	38.6	114.3	882	2.2	7.349
16	"	51.0	1.9	41.0	109.7	884	2.1	7.806
17	"	59.0	4.9	19.0	66.8	896	1.0	3.618
18	"	79.0	4.2	20.0	60.2	951	0.9	3.808
19	"	96.0	3.4	32.0	99.7	1008	2.0	6.093
20	"	71.5	3.0	32.0	116.0	1048	2.5	6.093
21	"	52.5	1.7	34.0	107.90	1015	2.2	6.473
22	"	111.5	3.2	35.2	103.9	1117	2.2	6.685

Table 3 - Flue gas analysis

Test No.	Flue gas composition, vol%			
	Carbon Dioxide		Oxygen	
	Average measured	Theoretical	Average measured	Theoretical
1	9.3	9.2	11.3	12.7
2	8.9	8.2	12.1	13.7
3	11.0	11.1	10.3	10.9
4	7.5	11.2	9.0	10.9
5	13.2	13.1	7.0	9.2
6	15.9	14.6	5.2	7.8
7	15.6	15.2	3.4	7.2
8	15.9	15.2	4.0	7.3
9	9.9	11.7	10.7	10.5
10	12.0	11.1	8.9	11.0
11	12.8	12.4	7.9	9.8
12	12.5	12.0	7.1	10.2
13	12.3	13.5	7.1	8.8
14	17.5	17.4	3.9	5.2
15	16.7	16.6	3.2	5.9
16	17.7	18.3	2.3	4.4
17	15.0	14.0	5.8	8.3
18	14.9	16.4	3.9	6.2
19	15.1	15.8	4.7	6.7
20	17.8	13.6	2.8	8.7
21	18.6	15.5	2.7	6.9
22	16.2	16.6	3.1	5.9

Table 4 - Carbon and ash balance for Hat Creek coaly waste

Run No.	Mode of fuel feed	Fluidization velocity m/s	Total unburnt carbon kg	Total carbon kg	Combustion efficiency %	Total ash accounted for kg	Theoretical ash input kg
1	Inbed	2.4	-	20.5	-	20.9	35.4
2	"	1.9	-	13.4	-	-	23.1
3	"	1.8	-	14.3	-	-	24.6
4	"	1.7	-	6.0	-	15.9	10.3
5	"	1.5	-	25.9	-	51.6	44.7
6	"	1.6	0.17	10.6	98.4	26.4	18.3
7	"	1.4	0.28	23.4	98.8	40.0	40.3
8	"	1.8	0.25	18.4	98.8	28.7	31.7
9	Overbed	1.4	-	33.7	-	38.5	58.1
10	"	1.0	-	8.2	-	18.6	14.1
11	"	1.1	0.5	25.5	98.2	36.0	44.0
12	"	1.0	0.54	22.1	97.7	37.0	38.1
13	"	1.0	0.37	19.8	98.2	24.4	34.1
14	"	1.0	0.28	19.5	98.6	45.9	33.7
15	"	2.2	0.80	24.1	96.8	54.9	41.6
16	"	2.1	0.27	12.3	98.2	27.7	22.4
17	"	1.1	0.32	15.1	97.9	38.7	25.0
18	"	1.1	-	20.2	-	33.9	34.8
19	"	2.0	-	24.5	-	34.2	42.2
20	"	2.5	-	31.5	-	37.4	31.5
21	"	2.2	-	13.4	-	-	23.1
22	"	2.2	-	28.4	-	46.0	49.1

- = result not available

Table 5 - Screen analysis of bed ash from Hat Creek coaly waste

Canadian standard sieve		Ash (test 13) 800°C		Ash (test 17) 900°C	
mm	mesh	wt%	cummulative wt%	wt%	cummulative wt%
-4.76	-4	1.2	1.2	0	0
-4.76 + 3.36	-4 + 6	7.7	8.9	4.9	4.9
-3.36 + 2.36	-6 + 8	16.3	25.2	19.3	24.2
-2.36 + 1.68	-8 + 12	13.3	38.5	16.8	41.0
-1.68 + 8.41	-12 + 20	23.7	62.2	30.7	71.7
-0.841 + 0.425	-20 + 40	14.7	76.9	16.6	88.3
-0.425 + 0.210	-40 + 70	13.5	90.4	7.6	95.9
-0.20 + 0.106	-70 + 140	8.9	99.3	3.4	99.3
-0.106	-104	0.7	100.0	0.7	100.0